Lagrangian Sampling of the Mississippi River, 1999: Work Plan

Purpose and Scope

Nitrogen (N) from the Mississippi River Basin (MRB) has been implicated as being the principal cause of hypoxia in the Gulf of Mexico. Current estimates of the flux and sources of nitrogen in the MRB assume that N transport in the main stem of the Mississippi River is conservative, with little loss of N to denitrification. If this assumption is significantly in error, the flux of N from the upper MRB may be overestimated and N flux from the lower MRB may be underestimated. Currently, little is known about the magnitudes or relative importance of in-stream processes such as denitrification, biological assimilation, volatilization, or nitrification in transforming N species in the Mississippi River or in releasing gaseous forms of N to the atmosphere. The principal goal of this study is to determine what happens to N as water flows down the Mississippi River from the upper Midwest to the Gulf of Mexico. A secondary goal is to determine in-stream rates of herbicide degradation. To accomplish these goals we propose to collect a Lagrangian set of samples on the Mississippi River in late July and early August 1999. The collection time of each sample will be carefully scheduled so that, theoretically, the same water mass will be sampled numerous times along a 1,400 mile reach of the river. Each sample will be analyzed for nutrients, dissolved organic carbon, stable isotopes of nitrate, water isotopes, C, N, and S isotopes in particulate matter, dissolved N gases, major cations and anions, and selected herbicides and herbicides metabolites. Samples will be collected at 17 sites including 7 NASQAN stations and 10 tributaries or Mississippi River locations that are not current NASQAN stations.

Specific hypotheses to be tested are:

1. A mass balance for the Mississippi River between Keokuk, IA and the Gulf of Mexico shows a net loss for N but not for water, or conservative tracers such as chloride or atrazine.
2. The magnitude of the N loss is large enough to produce an increase in the isotopic ratios ($\delta^{15}N$ and $\delta^{18}O$) in the nitrate ion, indicating denitrification is a significant removal mechanism.
3. The magnitude of nitrate loss is consistent with the amount of dissolved N gases (N_2 and N_2O) measured in river water.
4. In-stream degradation of herbicides results in an increase in the ratio of metabolite to parent herbicide concentrations.

Sample Collection and Processing

Sampling Sites and Target Sampling Times

The 17 sites to be sampled and the sampling schedule are listed in table 1. Site locations are shown on figure 1. The schedule has been designed to allow sampling of the same water mass at numerous locations along the river and to minimize non-weekday sampling. To accomplish this, sample collection must begin on Tuesday July 20 at approximately 1300 hours at Clinton, IA (river mile 1466) and end at

Belle Chasse, LA (river mile 73) on the morning of August 6. The estimated travel time for the water mass is 16 3/4 days. The target date and time for collection of each sample is given in table 1. The table also shows the targeted elapsed time for each sample since the Clinton sample and the theoretical time of travel time for a water mass from Clinton to Belle Chasse using a transport model (Broshears and Clark, in prep.). The target sampling time has been adjusted so that sampling will only be done during daylight hours. Close adherence to the target sampling time is of critical importance for the success of this project. **It is extremely important that samples be collected at the scheduled dates and times.**

Samples to be Collected

The following samples are to be collected:

NASQAN Sites:

1. All samples required by NASQAN
2. Filtered sample for N and water isotopes (see table 2 for volume required)
3. Dissolved gasses (2 special bottles and 1 vial will be provided)
4. Suspended organic material (glass fiber filter)
5. Herbicides/metabolites (for Thurman); (3 125 ml amber bottles)

Non NASQAN Sites:

1a. Nutrient/DOC sample (NASQAN schedule 1010, delete SOC sample)
1b. Major cation/anion sample (schedule 2701)
2. Filtered sample for N isotopes (see table 2 for volume required)
3. Dissolved gasses (2 special bottles and 1 vial will be provided)
4. Suspended organic material (glass fiber filter)
5. Herbicides/metabolites (for Thurman); (3 125 ml amber bottles)

Collect all samples **except the dissolved gasses** with a depth integrating sampler (where conditions are appropriate for this collection method) from three or more verticals using NASQAN/NAWQA protocols (Shelton, 1994). Samples from the vertical profiles will be composited in a glass, polyethylene, or Teflon container, as appropriate. All sampling equipment will be cleaned according to NASQAN/NAWQA protocols. The dissolved gas samples will be collected as point samples at mid-river and approximately mid-depth.

Field Measurements

The following field measurements are needed at each site. Please record all information on a field sheet and send a copy to Bill Battaglin in Denver.

1. Streamflow (measured or from rating curve)
2. Alkalinity
3. pH
4. Dissolved oxygen

5. Barometric pressure (need for DO and dissolved gasses)
6. Temperature (both air and water)
7. Specific conductance

Processing Samples

Nitrogen Isotope Samples: Samples will be filtered through a 0.45-micrometer cartridge filter into 1-liter or 1-gallon pre-cleaned polyethylene bottles, chilled without preservative, and sent on ice to Bill Battaglin at the USGS in Denver (see address below). If the filters clog, samples can be pre-filtered using a glass-fiber filter. All N isotope sample bottles will be labeled "LAG99_ISO", and should include the site name, site id, date and time of sample collection, and name of collector. Table 2 gives the expected nitrate concentration and volume of sample to be collected at each site.

Water Isotope Samples: No field processing of these samples is required. We will take the small quantity of water required for this sample from the N isotope sample after it arrives in Denver.

Nitrous Oxide Samples: Samples for nitrous oxide (N_2O) will be collected at each site, and analyzed by Pete McMahon in Denver. Special septum vials and syringes will be provided for the collection of these samples. The procedure will require a special set-up. See the appendix and figure 2 for details on the sample collection method. Label the vials with the site name, date, time and the code LAG99_$N_2$0. Place bottles inside a ziplock bag, chill, and ship in same cooler with the isotope samples to Bill Battaglin in Denver. See table 3 for the type of sample collection and the schedule of QA samples.

Dissolved Gases Samples: Samples (2 bottles) for dissolved gases (N_2, Ar, O_2, and CH_4) will be collected at each site. The samples will be analyzed in the Reston Gas Laboratory. The left over N2 gas may be analyzed for isotopes by J.K. Bohlke in Reston. Special sample bottles, stoppers, and syringe needles will be provided. The collection of these samples will require a special set-up that is nearly the same as for the nitrous oxide samples. See the appendix and figure 2 for details on the sample collection method. These sample bottles are pre-weighted and labeled with a serial number that is also printed on the bottle sleeve. Do not write on the bottles, but label the sleeves with the bottle serial number, site name, date, time and the code LAG99_GAS. Place bottles inside a ziplock bag, chill, and ship in same cooler with the isotope samples to Bill Battaglin in Denver. See table 3 for the type of sample collection and the schedule of QA samples.

Suspended Organic Material: Suspended sediment for isotopic analysis of $\delta^{15}N$, $\delta^{13}C$, and $\delta^{34}S$ of the suspended organic material will be collected will each sample. (This sample is being routinely collected at all NASQAN sites). Approximately 1 liter of water will be filtered through a 0.7 micrometer heat-cleaned glass-fiber filter (142 mm diameter) using a peristaltic pump and an aluminum plate filter. The

filtered water is normally used for pesticide or herbicide samples. After filtration of the sample, the glass fiber filter will be placed on a small sheet of clean aluminum foil using tweezers. The filter will be folded in half, and then into quarters using the tweezers, keeping the sediment on the inside. The filter will be wrapped in the aluminum foil, and labeled with the station name, ID number, sampling date, and time. The filter will be placed in a ziplock bag, chilled after collection, and shipped to William Battaglin in Denver with the N isotope sample. Label the filter with the code LAG99_SED. See appendix I for more detailed sample collection instructions.

Herbicides/metabolites Samples: Filter water through heat-cleaned, 0.7 micrometer glass fiber filters into 3 (three) 125-ml baked amber glass bottles. Fill bottles, label with site ID, site name, date, time, and the code "NAS". Place samples in a large ziplock bag, chill and ship to Mike Thurman at the address below. Use special care in packing the samples to avoid breakage. Use adequate packing material.

E.M. Thurman
U.S. Geological Survey
4821 Quail Crest Place
Lawrence, KS 66049
(785) 832-3564

Quality Assurance: Quality assurance (QA) samples will be collected at selected sites to provide information on the variability and bias of the measured isotopic ratios and gas data. These samples will consist of concurrent replicates, in which are two or more samples that are collected as closely as possible in time and space, but processed, handled, and analyzed separately; and trip blanks (nitrous oxide only), which are samples that are prepared in the laboratory and carried in the field, but not collected in the field. Collection of concurrent replicate samples requires two separate passes at each vertical in the cross section, to be composited in separate vessels. Tables 2 and 3 list sites at which should QA samples are to be collected. QA samples should be labeled with sampling times that are later than the primary sample in order to distinguish them from each other. Trip blanks will be collected for nitrous oxide gas only. **Concurrent replicates are required for:**

nutrients
nitrogen isotopes
nitrous oxide gas
dissolved gases.

Table 1. Sampling sites, target time of sample collection, elapsed time in hours from collection of first sample, and theoretical water travel time in hours from Clinton, IA.

Sampling site name	Target date of sample collection	Target time of sample collection	Elapsed time (hours) since Clinton sample	Theoretical travel time (hours)	River mile above Head of Passes
Mississippi River at Clinton, IA	Tuesday, 7/20	1300	0	0	1,466
Iowa River at Wapello, IA	Wednesday, 7/21	1300	24	24	1,388
Mississippi River at Keokuk, IA	Thursday, 7/22	0700	42	42	1,318
Des Moines River at Mississippi junction	Thursday, 7/22	0900	44	43	1.315
Missouri River at Hermann, MO	Friday, 7/23	0800	67	60	?
Illinois River at Mississippi junction	Saturday, 7/24	0700	88	84	1,172
Mississippi River at Grafton, IL	Saturday, 7/24	1000	91	85	1,171
Mississippi River at Thebes, IL	Monday, 7/26	0800	139	138	998
Ohio River at Grand Chain, IL	Monday, 7/26	0800	139	138	954
Mississippi River at Memphis, TN	Wednesday, 7/28	1600	195	198	735
Mississippi R. above Arkansas junction	Friday, 7/30	1300	240	240	583
Arkansas River at Mississippi junction	Friday, 7/30	1600	243	240	582
Mississippi River at Vicksburg, MS	Monday, 8/2	0800	307	306	436
Yazoo River at Mississippi junction	Monday, 8/2	1000	309	307	437
Mississippi River at St. Francisville, LA	Wednesday, 8/4	0800	355	348	266
Atchafalaya River at Melville, LA	Thursday, 8/5	0800	379	?	?
Mississippi River at Belle Chase, LA	Friday, 8/6	0800	403	402	73

Table 2. Map ids (figure 1), sampling sites, expected nitrate concentration, volume of sample, in liters, to be collected for isotope analysis (does not include water needed for QA samples or other analytical schedules), and sites where concurrent replicate samples are to be collected.

Map id	Sampling site name	NASQAN	Site number	Expected nitrate concentration in mg/L	Sample volume, in liters	Collect a concurrent replicate sample
1	Mississippi River at Clinton, IA	yes	05420500	1.0 - 3.0	6	yes
2	Iowa River at Wapello, IA	no	05465500	5.0 - 10.0	2	no
3	Mississippi River at Keokuk, IA	no	05474500	2.0 - 5.0	4	no
4	Des Moines River at Mississippi junction	no	4	5.0 - 10.0	2	no
5	Missouri River at Hermann, MO	yes	06934500	1.0 - 3.0	6	no
6	Illinois River at Mississippi junction	no	5	1.0 - 5.0	4	no
7	Mississippi River at Grafton, IL	yes	05587455	2.0 - 5.0	4	yes
8	Mississippi River at Thebes, IL	yes	07022000	2.0 - 4.0	4	yes
9	Ohio River at Grand Chain, IL	yes	03612500	0.5 - 2.0	8	yes
10	Mississippi River at Memphis, TN	no	07032000	1.0 - 3.0	6	no
11	Mississippi R. above Arkansas junction	no	11	1.0 - 3.0	6	yes
12	Arkansas River at Mississippi junction	no	12	0.05 - 0.5	16	no
13	Mississippi River at Vicksburg, MS	no	07289000	1.0 - 2.0	6	no
14	Yazoo River at Mississippi junction	no	14	0.05 - 1.0	12	no
15	Mississippi River at St. Francisville, LA	yes	07373420	1.0 - 2.0	6	yes
16	Atchafalaya at Melville, LA	yes	07381495	1.0 - 2.0	6	no
17	Mississippi River at Belle Chase. LA	no	07374525	1.0 - 2.0	6	no

Table 3. Map ids (figure 1), sampling sites for nitrous oxide and dissolved gasses, collection method for gas samples, and sites where replicate and trip blank gas samples are to be collected. (all gas samples will be collected as point samples. See appendix for details)

Map id	Sampling site name	Gas sample collection method	Collect a concurrent replicate sample	Process a trip blank
1	Mississippi River at Clinton, IA	Centroid	yes	no
2	Iowa River at Wapello, IA	Centroid	no	no
3	Mississippi River at Keokuk, IA	Centroid	no	yes
4	Des Moines River at Mississippi junction	Centroid	no	no
5	Missouri River at Hermann, MO	Centroid	no	no
6	Illinois River at Mississippi junction	Centroid	no	no
7	Mississippi River at Grafton, IL	Centroid	yes	no
8	Mississippi River at Thebes, IL	3 sample cross-section	yes	no
9	Ohio River at Grand Chain, IL	3 sample cross-section	yes	no
10	Mississippi River at Memphis, TN	Centroid	no	yes
11	Mississippi R. above Arkansas junction	6 sample cross-section	no	no
12	Arkansas River at Mississippi junction	Centroid	no	no
13	Mississippi River at Vicksburg, MS	Centroid	yes	no
14	Yazoo River at Mississippi junction	Centroid	no	no
15	Mississippi River at St. Francisville, LA	3 sample cross section	yes	no
16	Atchafalaya at Melville, LA	Centroid	no	no
17	Mississippi River at Belle Chase, LA	Centroid	no	yes

Appendix

Determining where and when to sample:

(1) Determine which sites are to be sampled and when to sample from table 1.

(2) Determine the volume of the isotope sample to be collected at each site from table 2.

(3) Determine which sites are to have concurrent replicate samples (nutrients and isotopes) collected from table 2, and concurrent replicate gas samples from table 3.

Collect the following samples:

(1) Determine what samples to collect from table 4.

Table 4. Samples to be collected at NASQAN and NON-NASQAN sites

NASQAN sites	NON-NASQAN sites
All scheduled NASQAN samples	Schedules 1010 (nutrient, DOC), 2701 (major cations and anions)
Nitrogen isotope sample	Nitrogen isotope sample
Nitrous oxide sample	Nitrous oxide sample
Dissolved gas (N_2, argon) sample	Dissolved gas (N_2, argon) sample
Glass fiber filter for suspended material (included in NASQAN sample)	Glass fiber filter for suspended material
Herbicide/metabolite samples for Thurman (may be included in NASQAN sample)	Herbicide/metabolite samples for Thurman
Field measurements	Field measurements

On a field sheet, record field measurements listed below. Send copy of field sheet to Bill Battaglin in Denver, along with isotope samples.

streamflow
pH and alkalinity
barometric pressure
dissolved oxygen
temperature (both air and water)
specific conductance

Nitrogen Isotope Sample Collection

(1) Pre-clean all sampling equipment according to NASQAN/NAWQA protocols.

(2) Collect the required volume of water (table 2) using a depth integrating sampler (where conditions are appropriate for this collection method) from three or more verticals following NASQAN/ NAWQA protocols (Shelton, 1994). Samples from the vertical profiles can be composited in glass, polyethylene, or Teflon containers.

(3) Label all sample bottles clearly with waterproof marker or preprinted labels. The minimum information on the label should be the site name, site id, date, time of sample collection, as shown below:

Iowa River at Wapello, IA
5465500
06/18/98 @ 10:00 am
LAG sample collected by Joe Water and Jane Stream

(4) Filter specified sample volume (from table 2) through a 0.45-micrometer cartridge filter into 1-liter or 1-gallon pre-cleaned polyethylene bottles. Chill samples without preservative, and send on ice to William Battaglin at the USGS in Denver (see address below):

William A. Battaglin
U.S. Geological Survey
6th Ave. & Kipling
Denver Federal Center
Bldg. 53, Room F-1200
Denver, CO 80225 - (303) 236-5950 x202

Schedules 1010 and 2701 (non-NASQAN sites only)

(1) Collect bottles for nutrient analysis (schedule 1010, requires 125-ml FCC bottle; one 125-ml WCA; 1 100-ml LCO113, and 1 F LC0305 - silver filter).

(2) Collect bottles for major ions (schedule 2701, requires one 250-ml FA bottle, one 250-ml RU bottle, and one 500-ml FU bottle).

(3) Include the site name, site id, date, and time of sample collection.

(4) Send samples to the USGS NWQL using the standard procedure. **Charge the analytical costs for these samples to the Mississippi Basin NASQAN account.**

Suspended Material on Glass Fiber Filter

(1) This sample is being routinely collected as part of NASQAN. Collect suspended material by filtering about 1 liter of water through a 0.7 micrometer heat-cleaned glass-fiber filter (142 mm diameter) using a peristaltic pump and an aluminum plate filter. This can be done as part of other sampling activities (i.e. during the processing of a pesticide sample) or as a separate step.

(2) After filtration of the sample, place the glass fiber filter on a small sheet of clean aluminum foil using tweezers. Fold the filter in half, and then into quarters using tweezers, keeping the sediment on the inside. Wrap the filter in the aluminum foil, and labeled with the station name, ID number, sampling date, and time.

(3) Place the filter in a ziplock bag, keep chilled after collection, and ship to William Battaglin in Denver with the rest of the isotope samples.

Nitrous Oxide Gas Sample Collection

This sample will be collected by pumping water from the river to the surface using a peristaltic or fluid metering pump and a length of Tygon or copper tubing. Water will be collected from the discharge end of the tubing in a syringe before it contacts the atmosphere. The water from the syringe will then be injected into a vial containing argon gas.

(1) We will furnish you pre-cleaned septum vials that are flushed with Argon gas, a 10 ml syringe, a 30 ml syringe, and a length of tubing. **Do not remove the septum** from the septum vial.

(2) Consult table 3 for the type of sample to be collected and to determine if a QA sample is scheduled. At most sites, samples will be from a single point from near the centroid of flow at mid depth. At 3 sites, a sample will be collected from mid-depth at three locations in a cross-section across the river. At one site, a sample will be collected from two depths (mid-depth and near bottom) at three locations in a cross-section across the river.

(3) Bring the temperature of the empty gas vials to river temperature. Do this by immersing the vials in a bucket or ice chest of river water at the start of your sampling. Leave the empty vials in the bucket/ice chest until you are ready to use them. This will allow the argon gas inside the vial to come to the approximate river temperature. Replace the water in the bucket/ice chest periodically to make sure it stays near river temperature.

(4) Attach a length of Tygon or copper tubing (We will furnish this) to the sampler weight or any weight that can lower the end of the tubing to about mid-depth. You will have to use your ingenuity to attach the tubing to the weight. You also will probably need to attach the tubing to the sampler cable every ten feet or so to keep the river current from pulling the tubing loose. Do not fasten the tubing so tight that it restricts the flow of water. Iowa will be the first to do the gas sampling and we will pass on any suggestions they have to let others know what works best.

(5) Once the tubing is secured to the sampler/weight, lower the end of the tubing to about mid-depth at the desired location in the river. Attach the other end of the tubing to the Viton tubing on the suction end of the peristaltic/metering pump. Pump water from mid-depth in the river to the surface. Pump for several minutes to flush the tubing and to remove all air bubbles. Shake tubing occasionally to help remove the air bubbles. **It is extremely important to get all air bubbles out of the tubing.**

(6) Trip blank QA samples should be carried to the field and immersed in river water like the other vials, **but do not puncture the septum** as described in the next step. Mark these vials with the site number and return them with the other samples.

(7) While the pump is flushing the tubing, prepare the septum vial for use as follows:

a) Remove septum vial from the bucket/ice chest and dry it with a Kimwipe.

b) Insert the needle of the **10-ml glass syringe** into the septum of the argon-filled vial and let the gas pressure equilibrate for a few minutes. The plunger in the syringe should rise if the bottle is over-pressured. **Do not depress the plunger and inject air into the vial.** Remove the needle from the septum after equilibration. The same needle can be used on the plastic syringe.

c) Insert the needle of the **30-ml plastic syringe** into the septum of the argon-filled vial and withdraw 15 ml of gas. Remove the needle from the septum and expel the gas through the needle to the atmosphere.

d) Remove the plunger from the **30-ml syringe**. Insert the tubing from the discharge end of the pump to the barrel of the syringe. Allow the syringe barrel to fill from the bottom up and overflow. After allowing the syringe barrel to overflow for a minute or two slowly remove the tubing from the barrel leaving an inverted meniscus of water on the barrel. Carefully and quickly reinsert the plunger into the syringe taking care not to introduce any air bubbles. Inspect the syringe barrel for bubbles. If you see any bubbles, empty the syringe and repeat step d.

e) Slowly expel water from the syringe through the needle by depressing the plunger until exactly 15 ml of water remains in the syringe. Then, insert the needle through the septum of the argon-filled vial and slowly inject the 15 ml of water into the vial.

f) Note that both the glass and the plastic syringe can be used for more than one sample, but a new needle should be used for each sample.

(8) Record the air temperature, water temperature and barometric pressure and include these data on the field sheet. Label all sample bottles clearly with waterproof marker or preprinted labels with the site name, site id, date, time of sample collection.

Dissolved Gas Sample (N_2, Argon) Collection

These samples of N_2 Ar, O_2 and CH_4 gas will be analyzed by Mike Doughten, Peggy Widman, and J.K. Bohlke in Reston, VA. This sample is collected in duplicate.

(1) Collect this sample immediately after (or before) the nitrous oxide sample, since both use the same setup. These samples are not to be filtered and the idea is to fill the bottles with water without leaving ANY air bubbles in the bottles.

(2) You will receive pre-cleaned and weighted bottles prepared by the Reston gas laboratory. A serial number will be printed on each bottles, and on the foam sleeve they come in. Please keep the bottles and sleeves together and add label information only on the sleeve. Do not write on this bottle. Each team will get 2-3 extra bottles to use in case of breakage or other damage.

(3) Consult table 3 for the type of sample to be collected and if a QA sample is scheduled. At most sites, samples will be from a single point at mid-depth near the centroid of flow. At 3 sites, samples will be collected from mid-depth at three locations in a cross-section across the river. At one site, a sample will be collected from two depths (mid-depth and deep) at three locations in a cross-section across the river.

(4) Fill a large bucket or ice chest about half full with river water.

(5) Attach Tygon tubing to a sampler or weight and lower to the desired location in the river. (Same setup as for nitrous oxide sample). Using a peristaltic pump, pump water up from sampler and into the large bucket or ice chest.

(6) Each sample consists of two bottles. Remove the septum (stopper) from the bottles and insert a syringe needle until the tip slightly exits through the bottom of the septum. Repeat this step for the second bottle using a second syringe needle and the septum from the second bottle.

(7) Fill one of the bottles by inserting the discharge end of the tubing from the pump to the bottom of the bottle. Let the bottle overfill then place into the bucket while the water continues to enter the bottle. Gently tap or agitate bottle to remove all air bubbles. Then slowly remove the tubing leaving the bottle full. Keep entire bottle under water at all times.

(8) Raise the top of bottle just to the water surface in the bucket and add one pellet of KOH (potassium hydroxide) preservative (about 100 mg) to the bottle using tweezers. **Use extreme care. KOH is caustic and can cause burns if it touches the skin.** I have included a few extra pellets for each sampling team.

(9) Then resubmerge the bottle in the bucket and slowly insert the bottle septum, letting the excess water in the bottle escape through the syringe needle. The idea here is to get the septum into the bottle without letting any air in. It is important to use slow steady pressure when inserting the septum and to make sure that the septum is all the way down in the bottle.

(10) Take the syringe needle out of the septum while the bottle is still immersed in the bucket. Remove bottle from bucket and put the bottle back in its sleeve.

(11) Repeat steps 7-10 for the second bottle.

(12) Keep the samples chilled and upside down (septum side down) after collection, and ship to William Battaglin in Denver along with the nitrous oxide sample and the isotope sample. Label all sample bottle sleeves clearly with waterproof marker or preprinted labels with the site name, site id, date, and time of sample collection, and water temperature.

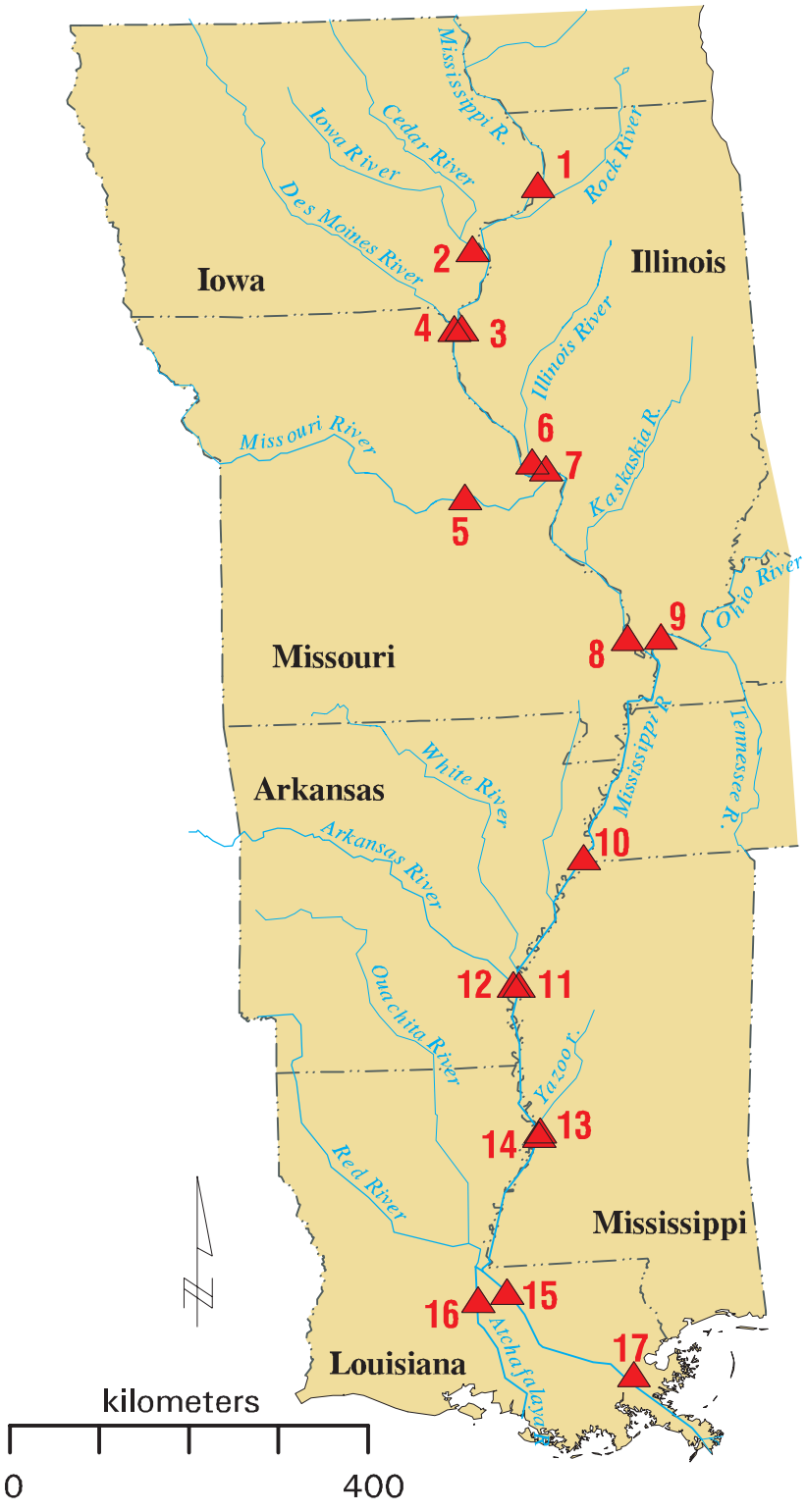
Sample Shipment:

(1) Samples are shipped to either the NWQL, Bill Battaglin, or Mike Thurman. Ideally, samples will be shipped on ice within one day of collection. Samples should be shipped to arrive at their destination during a week day. (No delivery on weekends).

William A. Battaglin
U.S. Geological Survey
6th Ave. & Kipling
Denver Federal Center
Bldg. 53, Room F-1200
Denver, CO 80225 - (303) 236-5950 x202

E.M Thurman
U.S. Geological Survey
4821 Quail Crest Place
Lawrence, KS 66049
(785) 832-3564

(2) Send EMAIL to Bill Battaglin (wbattagl@usgs.gov), Don Campbell (dhcampbe@usgs.gov), and Don Goolsby (dgoolsby@usgs.gov) with the date and time of sample collection as soon as possible after samples are shipped.


Mississippi R.
Cedar River
Iowa River
Des Moines River
Rock River
Illinois River
Missouri River
Kaskaskia R.
Ohio River
White River
Arkansas River
Ouachita River
Yazoo r.
Red River
Atchafalaya
Tennessee R.
Iowa
Illinois
Missouri
Arkansas
Mississippi
Louisiana
1
2
3
4
5
6
7
8
9
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11
12
13
14
15
16
17
kilometers
0
400

Figure 1 Location of sampling sites and map numbers for 1999 Mississippi Lagrangian study.

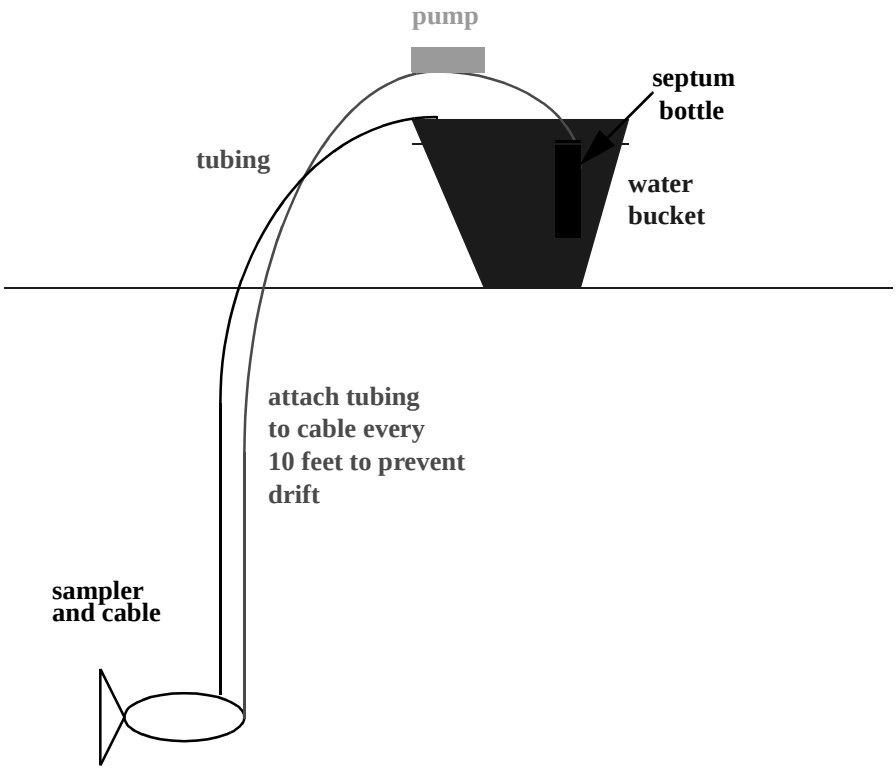

Figure 2. Diagram of nitrous oxide and dissolve gas sample collection set-up.